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The Opioid Crisis And Life Expectancy In The U.S.

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Abstract

Since the 1990s, when opioids started to be grossly over-prescribed, almost 450,000 people have died as a direct result of opioid abuse in the United States. This study analyzes the role the opioid crisis has in the decreasing life expectancy in the United States, a troubling trend given the enormous and growing national healthcare expenditure. Employing a multiple decrement model and national life expectancy tables, this paper removes the opioid-related mortality and develops a new life expectancy model. The actuarial analysis of the observed and estimated life expectancies reveals the impact of opioid-related deaths: overall, U.S persons are losing 153 days of life. For some groups of the population the situation is even worse, such as for non-Hispanic white males whose life expectation is reduced by 261 days.

Keywords

Opioids, life expectancy. multiple decrements, United States, actuarial analysis

Disciplines

Probability | Statistical Methodology | Survival Analysis

The opioid crisis and life expectancy in the USA

By

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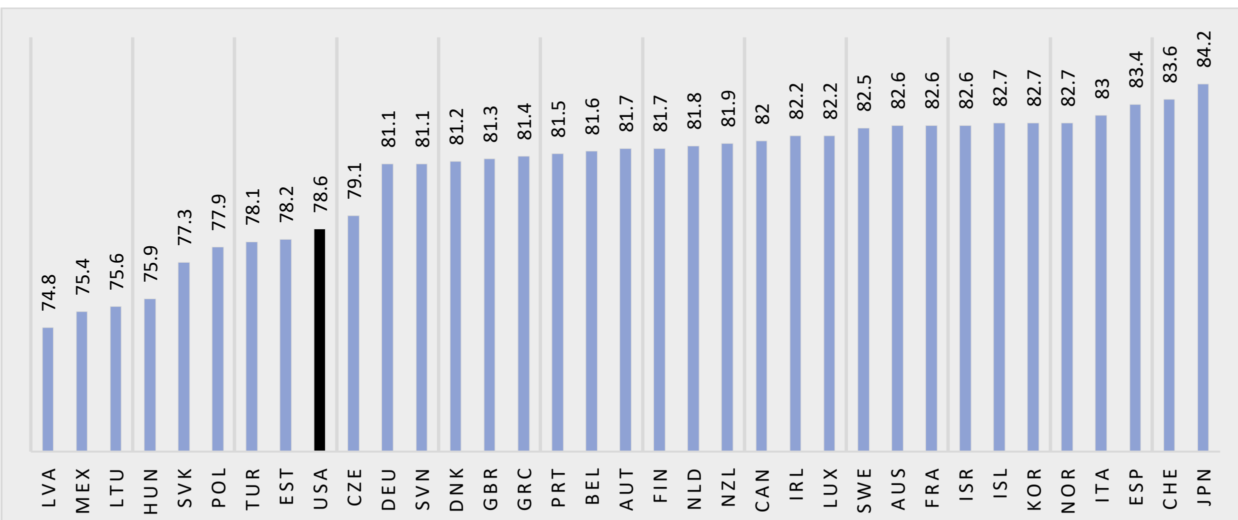
Abstract

Since the 1990s, when opioids started to be grossly over-prescribed, almost 450,000 people have died as a direct result of opioid abuse in the United States. This study analyzes the role the opioid crisis has in the decreasing life expectancy in the United States, a troubling trend given the enormous and growing national healthcare expenditure. Employing a multiple decrement model and national life expectancy tables, this paper removes the opioid-related mortality and develops a new life expectancy model. The actuarial analysis of the observed and estimated life expectancies reveals the impact of opioid-related deaths: overall, U.S persons are losing 153 days of life. For some groups of the population the situation is even worse, such as for non-Hispanic white males whose life expectation is reduced by 261 days.

Introduction

Life expectancy is a measure of how long a person can expect to live, on average. It summarizes the diseases, behavioral and lifestyle choices, dietary customs, and intentional and unintentional deaths that impact how long a person lives. Despite advances in cardiovascular diseases and other leading causes of death and ballooning healthcare expenditures, the life expectancy in the US has decreased since 2014 for three consecutive years[1]. The opioid crisis has greatly contributed to that decline (Muenning et al 2018). While more developed and wealthier countries tend to have higher life expectancies, the US is last among G7 countries and 28th out of 35 OECD countries (OECD 2019).

Figure 1: OECD Life Expectancies at Birth



[1] Preliminary data for 2018 shows a small increase in life expectancy (Kochanek, Anderson, and Arias 2020)

Given this troubling trend, it is critical to have a rigorous understanding of opioid-related morbidity. From 1999-2018, 446,032 people have died because of an opioid overdose (CDC WONDER; See Appendix B for query parameters). US adults consume about 80% of all opioids in the world, and one out of every three adults in the country use opioids (Rummans, Burton, and Lawson 2018). This health crisis arose out of three waves (CDC 2020). First, in the 1990s pharmaceutical companies touted opioids as an effective and safe treatment for chronic pain, leading to a huge rise in prescriptions. Then, in 2010 overdoses started to rise, and the use of heroin increased. The third wave hit in 2013 when synthetic opioids, such as fentanyl, flooded illicit markets.

Not everyone in the population has been affected equally. Middle-aged non-Hispanic whites have seen sharp rises in mortality and morbidity (Case and Deaton 2015). Furthermore, different types of opioids have impacted different population groups. Prescription opioids have previously driven mortality for whites, while illicit opioids, such as heroin, have affected minorities more. Those dynamics are changing rapidly with tighter regulations around prescriptions and the introduction of more potent and more deadly synthetic opioids, which are often abundant in illicit markets. Understanding this crisis is imperative for the federal and state governments as a large amount of tax revenues is appropriated to healthcare related expenditures. Health insurers and individual consumers also face significant costs due to opioid abuse.

Prior research has attempted to characterize opioid mortality. Measuring mortality related to a specific condition can be challenging due to the dependent nature of causes of mortality. Case and Deaton (2015) report on the particular impact of the opioid crisis on mortality for particular age groups and geographies. Muenning et al. (2018) also analyze the downward pressure on life expectancy due to opioids as a consequence of broad socio-economic trends. This study contributes to this growing body of work by obtaining the independent probabilities of cause specific mortality.

To effectively measure a given illness' mortality impact on life expectancy, the independent probability of being affected by it needs to be decoupled from every other possible illness that a person can get. For example, to be able to know how likely it is that a person will be affected by an opioid overdose, one must first know how likely it is for a person to not be affected by anything else. A multiple-decrement actuarial analysis, modeled by Lemaire (2005), accurately measures these probabilities. This technique has not been used in the recent medical literature.

Results

After applying the multiple decrement analysis on the CDC 2017 life expectancy model (Arias and Xu 2019), the latest available, to remove opioid-related mortality, the results show that the average US person loses 153.1 days due to opioid abuse (Table 1). The impact is much higher for males than females: 198.8 and 100.3 days, respectively.

Table 1

Impact of Opioid Abuse on Life Expectancy at Birth	
Population	*Impact (Days Lost)*
United States; All	153.1
United States; Females	100.3
United States; Males	198.8

The situation is alarming for everyone; yet, it is more alarming for some groups. Table 2 shows the results categorized by sex, race, and origin. As suggested by Case and Deaton (2015), non-Hispanic whites are more impacted by opioid abuse. At 204 potential days of life lost, Non-Hispanic whites lose almost twice as many days of life compared to non-Hispanic blacks, and almost three times as many as Hispanics. While still very concerning, Hispanics are the least impacted, with 76 days of life lost. The distinction by origin and not just race is important, as Arias and Xu (2019) note the significant difference between the groups in terms of life expectancy. The distinction between males and females is also drastic. Across all groups, females fare significantly better than males. Males face a life expectancy reduction about double or more of that of females. For Hispanic males, the reduction is three times as worse as Hispanic females, with 108 and 37 days lost, respectively. It is possible that these results are slightly underestimates as some opioid-related deaths were not considered as their age was unknown. Also, some studies suggest official opioid mortality data is significantly underestimated (Lowder et al, 2018).

Table 2

Impact of Opioid Abuse on Life Expectancy at Birth by Race/Origin

Population	*Impact (Days Lost)*
White; Non-Hispanic	203.9
White Females; Non-Hispanic	137.3
White Males; Non-Hispanic	261.4
Black; Non-Hispanic	110.9
Black Females; Non-Hispanic	69.2
Black Males; Non-Hispanic	147.5
Hispanic	75.9
Hispanic Females	36.8
Hispanic Males	107.9

The reduction to life expectancy is not constantly decreasing across ages, nor is it the highest at birth. Paradoxically, life expectancy increases marginally with age at first. This is due to the fact that surviving past the first few years of life increases the chance of living longer compared to life expectations at birth. Similarly, the impact on life expectancy from opioids increases marginally in the first decade or so. Most groups have the same trend. Figure 2 shows the pattern across age for the overall US population. At age 12, US persons lose the most days of life: 154 days (0.8 days more than at birth). Table 3 shows the maximum reduction of life expectancy due to opioids for each group that occurs at different ages. Non-Hispanic black and white males lose the most potential life as they grow up to age 17, where the reduction is almost 2 days more, both. For Hispanic females the impact on life expectancy is almost continually decreasing, reaching its peak at age 3.

Figure 2

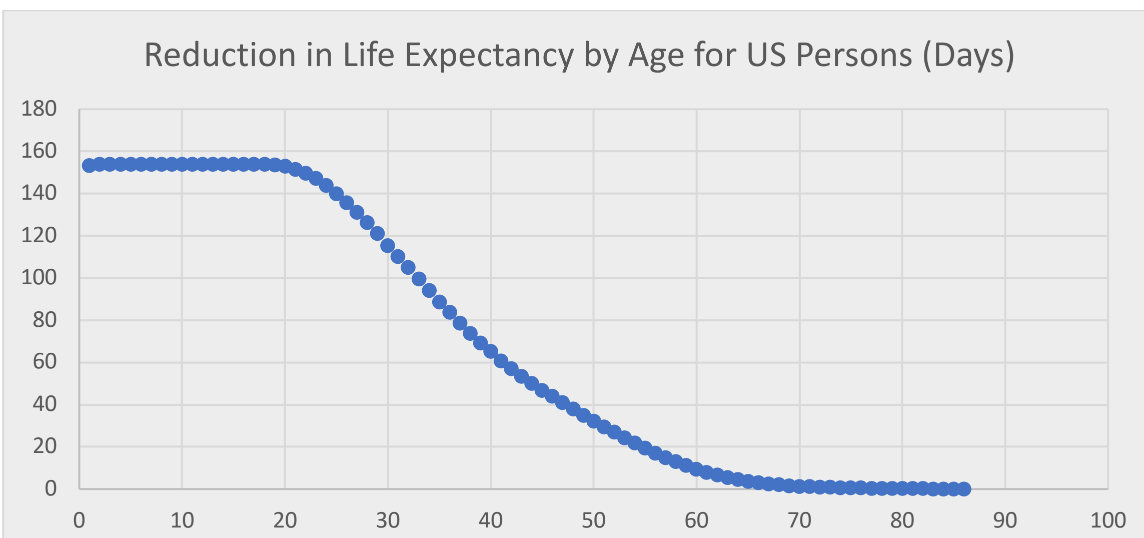


Table 3

Maximum Impact on Life Expectancy			
Population	*Impact (Days Lost)*	*Age*	*Increase*
United States; All	153.9	12	0.8
United States; Females	100.6	1	0.4
United States; Males	200.1	17	1.3
White; Non-Hispanic	205.0	13	1.0
White Females; Non-Hispanic	137.7	13	0.5
White Males; Non-Hispanic	263.0	17	1.6
Black; Non-Hispanic	111.7	1	0.9
Black Females; Non-Hispanic	69.4	1	0.2
Black Males; Non-Hispanic	149.0	1	1.6
Hispanic	76.3	14	0.4
Hispanic Females	37.0	3	0.1
Hispanic Males	108.6	14	0.7

Opioid abuse has been frequently discussed in terms of a middle age crisis. Table 4 shows the concentration of opioid deaths by 10-year age groups for 2017 data. The age group most heavily affected is 30-39-year-old people who account for almost 28% of all opioid related deaths. However, describing this health crisis as one that mostly affects middle-aged persons would not be appropriate. The 35-45 grouping, which includes the literal midpoint of life only accounts for 26%. The broader 30-50 age grouping includes 50% of opioid related deaths. Opioid abuse affects adults of all ages fairly similarly.

Table 4

Deaths by Age Segment	
Age Grouping	Deaths
0-9	0.1%
10-19	1.1%
20-29	20.9%
30-39	27.6%
40-49	20.8%
50-59	20.3%
60-69	7.8%
70-79	1.0%
80+	0.3%
Middle-Aged Crisis?	
35-45	25.5%
30-50	50.4%

Discussion

If opioid overdoses were its own category, it would be considered the 10th leading cause of death in the US after separation from unintentional injuries and suicides (WISQARS 2020). Further, 70% of opioid-related deaths occur among people 50 and younger. The country is losing tens of thousands of valuable and productive members of society each year. A loss of almost half a year, and in some cases over two thirds of a year, of life expectancy is very alarming. From the 1950s to 2014 life expectancy steadily increased, but then decreased for three continuous years until 2017. Over 50% of that decline is attributed to unintentional injuries and suicides, of which opioid overdoses are part of, according to Kochanek, Anderson, and Arias (2020). The authors also note preliminary reports that indicate a life expectancy of 78.7 years in 2018, a 0.1 rise from 2017. However, they also note that the small rise is only 25% due to a decrease in unintentional injuries. Further, opioid overdoses decreased by less than 2% from 47,600 in 2017 to 46,802 in 2018 (Wilson et al 2020). Wilson et al also note that the death rate for synthetic opioid increased by 10% from 2017 to 2018, while the rates for prescription-opioids and heroin decreased 4% and 14%, respectively. Unfortunately, it cannot be said that the opioid crisis is abating.

As the results show, this crisis does not impact all groups equally. Non-Hispanic white males are the most affected group of the population and special attention needs to be given to them. Interventions needs to be designed within cultural and racial context that address broader structural and social health determinants. Substance abuse treatments, prescription monitoring programs, distribution of naloxone, and partnerships with public safety need to be evaluated.

Methodology

To assess how much life expectancy would increase if opioid-related mortality were removed, the independent probability of dying from anything but opioids needs to be calculated. Surviving all possible causes of death (excluding opioids) is the complement. Integrating that last probability equation over all years of life yields the life expectancy at birth. A description of the methods and data sources continues below.

Step 1: Indep-P(death not opioids) = 1 – [1 – P(death)]^[P(death not opioids)/P(death)]

Step 2: 1 – (step 1)

Step 3: $\int_0^{t=\infty}((step\ 2) * force\ of\ mortality * t)dt$

In step 3, the limit of ∞ changes in practice because is the current limit on human life is 116 years (Senda 2019).

This integration cannot be calculated with discretized data. However, as modeled by Oblander, Park, and Lemaire (2016) on suicide rates in Japan and South Korea and by Lemaire (2005) on the impact of firearm deaths on life expectancy in the United States, calculations can be performed using discrete life expectancy tables. Mortality data can be obtained from the Center for Disease Control and Prevention's Wide-ranging Online Data for Epidemiologic Research (WONDER) and segregated by sex, age, and race.

To begin, the total probability of death ${}_nq_x^{(\tau)}$ needs to be separated by cause, or decrement. For this study, decrement (1) will be death by opioid, and decrement (2) will be all else. Thus: ${}_nq_x^{(\tau)} = {}_nq_x^{(1)} + {}_nq_x^{(2)}$. One-year probabilities for each year of age ($x = 0,1,2,\ldots$) are considered. For example, ${}_1q_3^{(1)}$ is the single year probability of dying due to opioids at age 3. When n = 1, ${}_1q_x^{(\tau)}$ is denoted as $q_x^{(\tau)}$ (omitted *n)*. However, the two probabilities are dependent on each other. For example, to die of opioid overdose a person must have survived all other causes. So, given that a person has survived up to age *x,* $q_x^{(1)}$ translates to the dependent probability of dying from age x to $x+1$ from opioid-related overdose. As a result of this inter-dependence, if the opioid-related mortality ($q_x^{(1)}$) decreases then the mortality of all else would increase ($q_x^{(2)}$). Additionally, a standard uniform distribution of deaths is assumed for total mortality and the opioid decrement. See Appendix B for specific formulas and descriptions.

For the calculations, $q_x^{(\tau)}$, the probability of dying between ages x and $x + 1$, is obtained directly from the CDC's 2017 life expectancy table. Next, $q_x^{(1)}$, the dependent probability of dying due to opioids is taken from the CDC WONDER platform. Death classifications followed the *International Classification of Diseases, Tenth Revision* (ICD-10) codes. See Appendix B for parameters. From the complement $q_x^{(2)}$ is readily obtained. As previously explained, the independent probabilities are necessary. With UDD, an exponential interpolation can be used to obtain the independent probabilities or *absolute rates of decrement* $q_x^{'(1)}$ and $q_x^{'(2)}$.

Next, a new life table can be developed to observe survival rates if opioid abuse ceased in the US. To begin, the modified number of people alive at each age, represented by $l_x^{'(\tau)}$, needs to be mapped out. Starting with age at $x = 0$ years, it will be truncated at $x = 85+$ years. By 85, opioid related deaths are very uncommon. At $x = 0$, the table will consider a group of 100,000 people alive. After a year, $l_{x+1}^{'(\tau)}$ can be derived from multiplying $l_x^{'(\tau)}$ by the probability for a person aged x to continue to live, which is the complement of $q_x^{(\tau)}$. Th new number of deaths for each age x, d_x', is calculated by the product of people alive at the beginning of the year, $l_x^{'(\tau)}$, and $q_x^{'(2)}$.

The previous allows for the calculation of the aggregate number of years lived by those alive at the beginning of each year, or total person-years lived L_x', until the start of the next year. With the UDD assumption, those who passed away live half a year, on average. Thus, when all person-years lived above age x are summed and then divided by the number alive at the beginning of the age-year x, the expectation of life is derived. The life expectation at birth, once opioid mortality is removed, e_x', is the sum of the total person-years lived from birth until death, divided by the number of people alive at $x = 0$. Finally, e_x' and all other calculations can be compared to the original life table and opioid mortality reports to understand the impact of the opioid crisis.

Conclusion

An actuarial multiple decrement analysis shows that opioid related mortality accounts for a 153 day, or 0.42 year, reduction in life expectancy in the United States as of 2017. Males face a reduction in life expectancy twice as large as that of females. Across ethic/racial groups, non-Hispanic whites are the most impacted, but all groups face a significant loss of life. A large majority of deaths are concentrated in people 50 and younger, resulting in a significant cost to society. Further, deaths due to opioid overdoses are often preceded by extended periods of addiction. With synthetic opioids flooding black markets, it is no longer just an over-prescription issue. Significant and multi-faceted interventions are urgently needed to tackle this crisis.

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Appendix A: Literature Review on Opioid-Related Mortality

Life expectancy is a commonly used metric to compare the health status of nations' citizens. It summarizes the diseases, behavioral and lifestyle choices, dietary customs, and intentional or unintentional deaths that impact how long a person, on average, lives in a given country. Among countries in the OECD, the United States ranks poorly. At a life expectancy at birth of 78.6 years, it ranks behind countries that spend a small fraction of their GDP on their healthcare system compared to the US (OEDC 2017).

For many decades, life expectancy in the US had been rising, albeit not as fast as in other rich countries (Muenning et al, 2018. In absence of "war, famine, and disease outbreaks," countries should see fairly linear improvements in life expectancy. This projection accounts for the general advancements in healthcare technologies and lower mortalities that come with time. Dowel et al (2017) also report that for three decades up until 2000, the US had seen an average annual rise in life expectancy of 0.2 years. From 2000 to 2014, that rise decreased to 0.15 years. Most alarmingly, recent statistics show that the trend is now reversed. Haskins (2019) reports that for the past three years, life expectancy in the US has been revised down. OEDC (2019) confirm that in 2014 it was reported at 78.9 years. But as of 2017, life expectancy is now at 78.6.

Case and Deaton (2015) also noted the very particular and worrisome trend that no other developed country was experiencing. They coined the term "deaths of despair" to describe the general sharp rise in mortality and morbidity that non-Hispanic whites (and particularly less educated whites) in the US were seeing. Case and Deaton highlight the opioid crisis and its related mortality as a significant contributor. Opioids were widely prescribed to treat real prevalent pain in society, yet they started to quickly be overprescribed and misused. Consequent regulation then drove substitution to heroin which was becoming cheaper and widely available. Hansen and Netherland (2016) also notice the growing concern over Americans turning to heroin when prescriptions were tightened. Muenning et al (2018, 1626) also note opioid-associated mortality as a weight on life expectancy, discussing how in 2016 over 60,000 deaths were reported to be due to opioids. Rudd et al (2016) from the CDC, emphasize the drastic increases in fatal drug overdoses. Since 2000 to 2014, drug-overdoses have risen by almost a 1.5 factor. And in just 2013 to 2014, mortality rates for prescribed opioids rose by 9%, heroin rose by 26%, and illicit synthetic opioids such as fentanyl rose by 80%.

While Hansen and Netherland (2016) concur with Case and Deaton (2015) on the rise of opioid-related mortality, they argue that it is not just a problem for middle-aged non-Hispanic Whites in the US. Similarly, Haskins (2019) discusses how the opioid crisis and related "deaths of despair" are rooted in socio-economic determinants. Hansen and Netherlands (2016) posit that while the prescription opioid crisis does primarily impact white communities, black and Hispanic communities have been severely affected by heroin use. Muenning et al (2018) argue that the opioid epidemic that is currently disproportionally affecting non-Hispanic whites sits on top of a "broad effect among all groups in the United States, not just less-educated whites." Synthetic opioids, like fentanyl, also affect black and Hispanic communities drastically. Those communities who have historically been more affected by heroin use than their white counterparts, who were prescribed opioids much more frequently, are now exposed to cheaper, stronger and more available synthetics.

But even as the current literature show alarming mortality associated with opioids, some studies suggest the numbers might be underestimated. In Indiana, Lowder et al (2018) studied a large under-reporting of overdose-related deaths as deaths caused by opioids. They found that from 2011-2016, “57.7% of accidental overdose deaths were unspecified and 34.2% involved opioids”. But of the unspecified deaths, over 80% were actually due to opioids. Further, different death-classification protocols across the country present issues. For example, states with decentralized medical examiner systems like Louisiana, Pennsylvania, Alabama, Montana, Indiana, and Delaware, saw over one third of overdose-related deaths reported as unspecified. Parallelly, Barocas et all (2018) also note a large underreporting of opioid abuse in Massachusetts due to possible sigma and systemic error.

Studies on life expectancy generally use CDC mortality reports from the National Vital Statistics System (NVSS). Death are categorized using the International Classification of Diseases, Tenth Revision. However, Iwanicki et al (2018) compared the quality of NVSS data to reported poison center calls. NVSS is the most complete data set, as all deaths are legally required to be reported to it. However, each case does not include many specifics and there is a one to two year lag before national reports are issued. On the other hand, calls to poison centers offer much more limited samples but have more detailed information. This is of particular interest when discerning between prescription opioid deaths and synthetic and illicit opioid deaths.

The current medical literature that measures impact in life expectancy does not have a consensus on how to do so. Dowell et all (2017) calculate differences in life expectancy at birth by partitioning using the change in the rate of deaths from unique causes for each age group for 2000 vs 2015. In contrast, Case and Deaton (2015) calculate deaths that would have been prevented from 1999 to 2013 by comparing real mortality rates observed per year with the proportions that would have been seen per year if mortality had decreased in the same way seen from 1979 to 1998. Because they use age-group averages and not individual age mortalities, some of their observed results can be attributed to statistical bias. Another study in Ontario, Canada by Gomes et al (2014) uses a different method as well. The authors estimate years of life lost, as opposed to lives saved, or deduced life expectancy at birth directly.

Lemaire (2005) introduces an actuarial multiple decrement technique to capture the direct impact on life expectancy by firearm deaths in the US. This method can be replicated to understanding opioid-related deaths and life expectancy. This paper uses this methodology as it is a better fit to identify causal relationships that impact mortality rates as it does not rely on age group averages.

Appendix B: Technical Notes

Uniform Distribution of Deaths : Linear interpolation of deaths across time intervals

UDD assumed for total mortality and the opioid decrement :

$$ {}_tq_x = \frac{t}{n} * {}_tq_x \quad \text{for } 0 \leq t \leq n. $$

$q_x^{(1)}$: Dependent probability of dying due to opioids between x and x + 1

Opioid-related morality rates were obtained from the CDC WONDER platform for National Center for Health Statistics. Death classifications followed ICD-10 codes X40–44 (unintentional), X60–64 (suicide), X85 (homicide), and Y10–Y14 (undetermined intent). For deaths related to drug overdoses, opioid mortality was coded with T40.0 (Opium), T40.1 (Heroin), T40.2 (Other opioids), T40.3 (Methadone), T40.4 (Other synthetic narcotics), and T40.6 (Other and unspecified narcotics). Some deaths can be due to multiple opioids; thus, categories are not mutually exclusive, but the over estimation effect is minimal. This protocol is defined by the Substance Abuse and Mental Health Services Administration and is standard reporting practice for how the CDC reports data (Scholl et all, 2019).

$q_x^{(2)}$: Dependent probability of dying not due to opioids between x and x + 1

Obtained from the difference between $q_x^{(\tau)}$ and $q_x^{(1)}$.

$q_x'^{(2)}$: Independent probability of dying not due to opioids between x and x + 1

An exponential interpolation between 1 and $q_x^{(2)}$ based on the ratio of deaths that are due to opioid abuse:

$$q_x'^{(2)} = 1 - [1 - q_x^{(\tau)}]\text{^}(q_x^{(2)} / q_x^{(\tau)})$$

l_x' : Modified number of people surviving to age *x*, without the opioid decrement

Starting using radix of 100,000 at age 0:

$$l_x' = l_{x-1}' * (1 - q_{x-1}'^{(2)})$$

Because 85 is the last year of age for which reliable population data is available, the new table show aggregated data for that cohort. Logically, at x = 85+ $q_x^{(\tau)}$ and $q_x'^{(2)}$ will equal 1, as death is certain for the infinite interval past 85. $q_{85+}^{(1)}$ is derived from the total number of deaths from opioids divided by the population over 85 years.

d_x' : Modified number deaths between ages *x* and *x* + 1, without the opioid decrement

$$d_x' = l_x' * q_x'^{(2)}$$

At x = 85+, deaths cover all of the remaining population.

L_x' : Total person-years lived between ages *x* and *x* + 1, without the opioid decrement

Obtained by counting one year for everyone that survived and a half year for everyone that died based on a uniform distribution of deaths throughout the year.

$$L_x' = l_x' * 1 + d_x' * 0.5$$

For $x = 0$, infancy mortality is heavily skewed towards the beginning of the year. A separation factor (a ratio of infant deaths for year *n* from infants born in year *n-1*), *f,* employed by a birth cohort method is provided in the technical notes of the 2017 Life Tables (Arias and Xu 2019). The following formula can then be used for L_0':

$$L_0' = l_0' * f + l_1' * (1 - f)$$

For the person-years lived calculation at the end of the table the following equation is required as employed by Oblander, Park, and Lemaire (2016):

$$_{\infty}L_{85}' = (E[T_{85}] * l_{85}') / (1 - {}_{\infty}q_{85}^{(1)})$$

T_x' : Modified total number of person-years lived above age *x*

Sum of all L_x' from age x and above.

e_x' : Modified expectation of life at age *x*

$$e_x' = T_x' / l_x'$$

From the difference of e_x' and e_x (from the original 2017 life table), the expected change in life expectancy if opioid-related deaths had not occurred is obtained. A year is considered as 365.25 days.